SCOTER: a Python program package for multiple-event location by using static and source-specific station correction terms

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Introduction

We present an open-source software package - **SCOTER** – for multiple-event location. The tool implements source-specific station terms (SSST) technique (Richards-Dinger & Shearer, 2000; Lin & Shearer, 2005) to reduce the effect of spatially correlated residuals caused by 3-D velocity structure. By using this technique, a set of P- and/or S-wave station corrections is computed iteratively for each source-receiver path. The calculated station terms are added to the travel times computed from the velocity model to take the unmodelled structure into account. Thus, the travel-time residual misfit function is a function of both the station terms and the hypocenter parameters (Nooshiri et al., 2017).

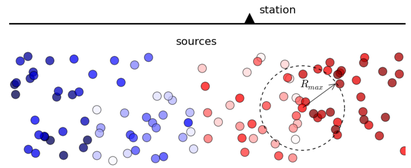


Figure 1: A cartoon illustrating source-specific station term calculation.

The basic algorithm applied is described by the following steps:

- All the earthquakes are located with the actual arrival times.
- SSST avlues are calculated for each source-receiver pair as the mean of the residuals from neighboring events located within a sphere of radius r_{max} around the target event.
- The original arrival time picks are corrected by the calculated SSSTs.
- The earthquakes are relocated with these corrected arrival times.
- The above steps are repeated iteratively.

Some Features of the SCOTER Program

- Supports local, regional, and teleseismic location.
- Adopted for non-linear, global-search location method implemented in the software package **NonLinLoc** (Lomax et al., 2000).
- Allows each neighboring event to be directly weighted according to the inter-event distance and residual performance.
- Uses **Pyrocko** toolbox and library for data handling (e.g. `QuakeML` data format).
- Can be run as a command-line tool:

```
# To get further help and a list of available options and subcommands:
$ scoter --help
# To get an example configuration file:
$ scoter init myconfig.sf
# To run SCOTER:
$ scoter go myconfig.sf --steps=A,B,C --parallel=8
```

Code Availability

`https://gitext.gfz-potsdam.de/nooshiri/scoter`

Application to the Seismicity Along the Northern Arctic Ridge

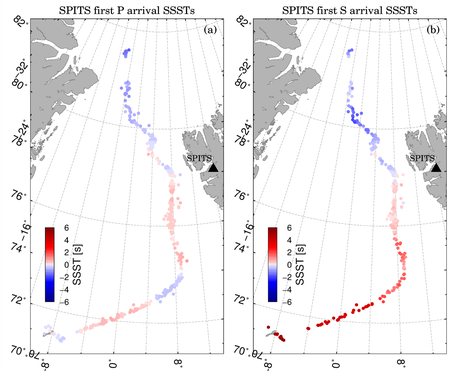
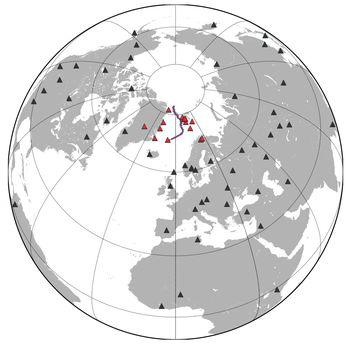


Figure 2: Calculated source-specific station terms (SSSTs) for regional seismic array SPITS for (**a**) first P arrivals and (**b**) first S arrivals. The SSST values are color coded and plotted at the event locations.



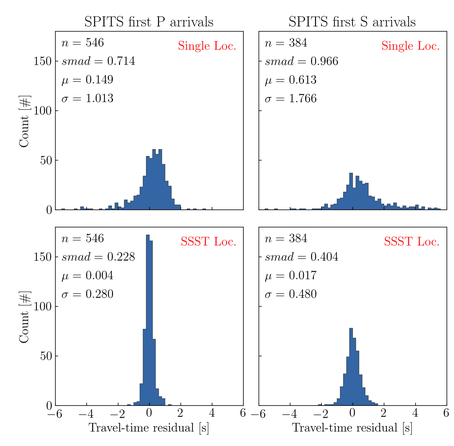
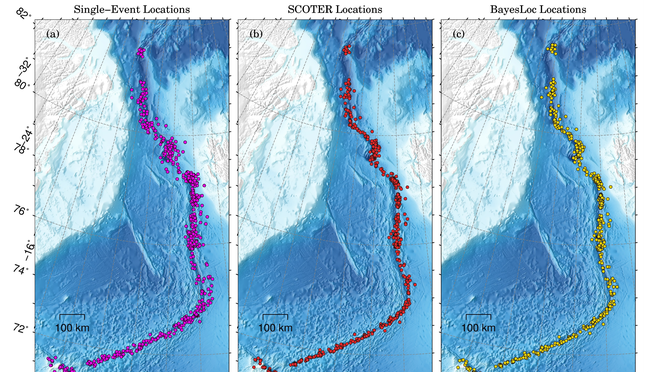


Figure 4: Histograms of the travel-time residuals from (**top**) single-event and (**bottom**) the SSST relocations for the station shown in Fig. 2. The scaled median absolute deviation (smad), mean, and sample standard deviation of each distribution are indicated on each panel.

Figure 3: Relocated seismicity in the Arctic Ridge using (**a**) a single-event, non-linear algorithm and (**b**) source-specific station correction terms (SSSTs) implemented in the `SCOTER` program, and (**c**) BayesLoc locations presented in Gibbons et al. (2017).



Dataset

A catalog of 614 events with magnitude range of M 2.0-6.0 in the Arctic region since 1998 has been generated using high-quality Pn and Sn readings on stations on both sides of the spreading ridge in addition to teleseismic P phases (Gibbons et al., 2017).

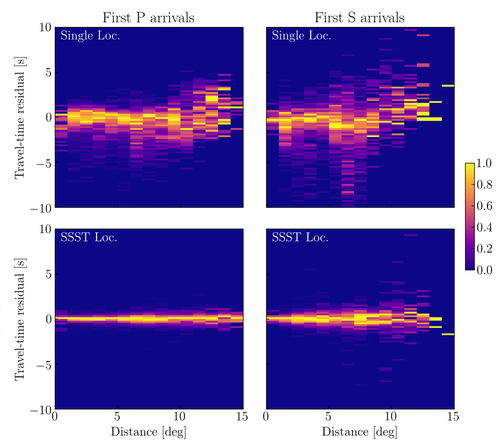


Figure 5: Frequency of occurrence (heat plots) of travel-time residuals for (**top**) single-event and (**bottom**) the SSST locations. The heat plots are normalized in each distance range so that the residual bin with the largest number of hits (the scaling cell) is assigned a value of 1.

Summary & Conclusion

- `SCOTER` is a publicly available software package that applies the station correction terms to perform precise relocations of earthquake hypocenters.
- `SCOTER` is run as a command line tool and provides a set of sub-commands to develop inputs (dataset, configuration etc) and export results (hypocenter parameters, travel-time residuals etc).
- Relocation results for the seismicity in the Arctic region demonstrate the method's viability in illuminating key features of the seismicity that are obscured by single-event locations.

References

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